A Matter of Perception

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ABSTRACT

This pilot study explores the possibility of cognitive training software Neurotracker (NT), to have potential beneficial effects for Traumatic Brain Injury patients with Sensory Processing Disorder. Five subjects with TBI and SPD trained for 5 weeks/21 sessions with Neurotracker. Pre-post training cognitive tests (WAIS TMTA, TMTB, LNS) and surveys were conducted to measure possible cognitive differences with no statistical significant results. However, significant improvement in Neurotracker scores were found. (α=.05, P=.043) between T1 (M=1.79, SD=0.44) and T2 (M =2.73, SD = 0.55) and positive changes associated with attention attention span, divided attention, (multiple) object tracking and motion sickness.

Keywords
Neurotracker, Sensory Processing Disorder, Traumatic Brain Injury, cognitive training, post-concussion treatment.

INTRODUCTION

People suffering from Traumatic Brain Injury (TBI) often get limited cognitive rehabilitation in the Netherlands forcing them to live with a wide variety of impairments in the dysfunctioning nature of cognition, perception, physicality and emotion and getting overwhelmed in these modalities, also known as sensory processing disorder (SPD). This may cause severe headaches, extreme fatigue and/or impaired cognitive functioning (Segal et al. ,2007) and may therefore cause major impairments in everyday life. SPD is likely the cause of impaired cognitive functions as among others: inhibition, attention and working memory.

Neurotracker (NT), a 3D-multiple object tracking (3D-MOT) training software, has been suggested to train and enhance attention, concentration, working memory and visual processing speed in sports and rehabilitation (Pearson et al., 2014). Different forms of research has been conducted to suggesting positive training effects on learning rate, attention, working memory and *inhibition* in (elite) athletes, military personnel, elderly, people with autism and mild Traumatic Brain Injury (mTBI) or concussion (Legault et al. 2013; Parsons et al. 2014; Parsons et al. 2014; Faubert 2016; Coady & Blackler, 2016; Faubert 2017). Studies also report improved rate of recovery after mild sensory stimulation after acute phases of mild Traumatic Brain Injury (mTBI), (Novack & Johnson, 1998; Cappaa et al.2003).
Despite these symptoms, impairments and research on SPD are widely known, there is no regular (post) rehabilitation program used (in the Netherlands) to decrease these symptoms or to stimulate cognitive functioning for further recovery.
This pilot study's aim is to explore the potential of cognitive training software NT on having a beneficial effect on SPD recovery by focusing on the following 3 topics:
1 NT's positive effect on cognitive functions associated with SPD.
2 Ability to improve in NT training for TBI subjects
3 Positive changes in symptoms of SPD after NT training

To measure changes in cognitive functioning associated with SPD, a small battery of tests will be conducted before and after the NT training program. Respectively Wechsler Adult Intelligence Scale (WAIS) will be used to measure changes in cognitive flexibility, attention and executive functioning using Trail Making Test A (TMTA), Trail Making Test B (TMTB). Working memory will be measured by the Letter-Number Sequencing (LNS) test of WAIS. These tests are often used by psychologists to measure cognitive (dys)functioning.
To report subject´s subjective experiences and possible changes in experiences of SPD, surveys are conducted before and after the training period.

METHOD

The 5 participants voluntarily participated in this pilot. All 5 female subjects aged 21 to 35 (M=28, SD = 5,83) have had severe TBI and suffer permanent brain damage with sensory processing disorder. They were no longer under rehabilitation treatment as post rehabilitation programs are unavailable.
All participating subjects were prior to their volunteering, thoroughly informed and made familiar with the training program and procedures. A psychologist and an occupational therapist supervised and conducted, prior to the training period, the cognitive tests TMTA, TMTB, LNS and a survey on sensory processing disorder. They gave permission to start the pilot after a careful assessment of taxability, risks and appointments including voluntary termination of participation in the pilot and privacy permission was given to start the pilot.
The first training sessions of the subjects were performed under supervision for safety and to give immediate coaching and feedback, which extended throughout the training period.

Task Procedure & Design

Neurotracker software is run on a computer screen while the test subjects wore blue-red 3D glasses to see a floating 3D box on the screen with 8 yellow targets inside it. Figure 1 shows and explains the training cycle in 4 phases: a), b) c) and d).

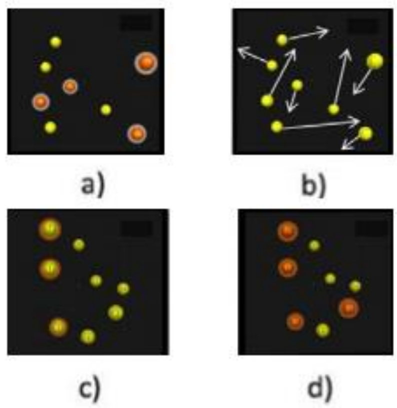

Figure 1: Phases in Neurotracker task a): Targets that need to be tracked by subject are highlighted, b) targets are moving for 6

seconds, c) subject chooses supposed previously highlighted targets, d) correct previously highlighted targets are shown. Taken from: "The Effect of Feedback on 3D Multiple Object Tracking Performance and its Transferability to other Attentional Tasks" (C. Perico, 2014)

When all targets were chosen for identification, a positive or negative sound was played which indicated success or a fault where after the cycle began again. An algorithm adjusted the training intensity per subject by adjusting the number of balls, speed and length of trial.

Training Procedure & Design

Prior to the training sessions each subject was tested with 3 cognitive tests (TMTA, TMTB and LNS). During the training period test subjects trained 1-3 times per week depending on their comfort for 5 weeks with each training consisting of approximately 20 minutes. After the training period all subjects were tested again on TMTA, TMTB and LNS and a second survey was conducted to note possible observed changes.

Data Analysis

Pre-post comparison of means of TMTA, TMTB and LNS were tested for significance. Nevertheless the data of NT, TMTB and LNS scores was normally distributed (Shapiro-Wilk tests for normality), nonparametric tests were used for more robust testing as no information is available about the distribution of the TBI population. Also little research is done on individuals with TBI in a training design.

RESULTS

Trail Making Test A

Figure 2 shows subjects 1, 4 and 5 have a (small) increase in task completion time, while subjects 2 and 3 show a decrease but not significantly.

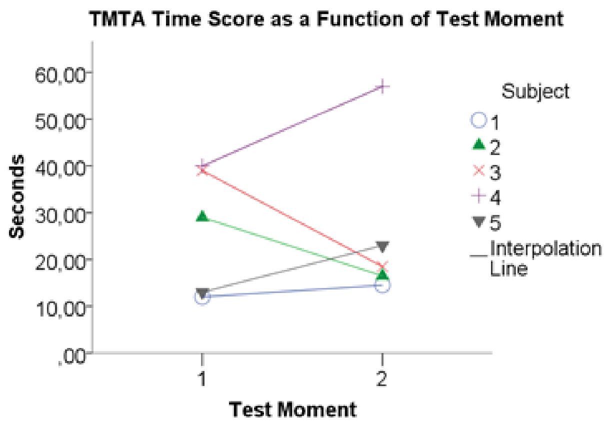

Figure 2: Scatterplot shows TMTA scores (in seconds) per test moment, before and after NT training.

Trail Making Test B

Only one individual showed an increase in task completion time (+20 seconds) between test moments.

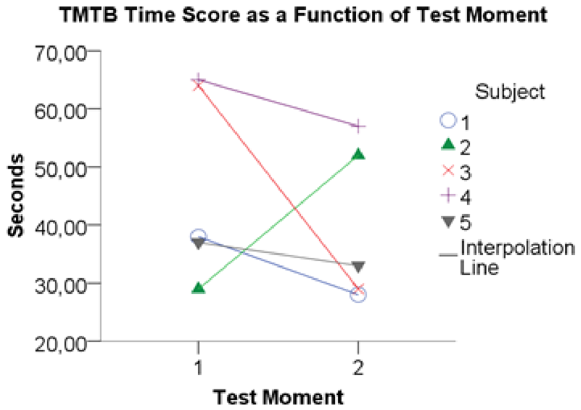

Figure 3: Scatterplot shows TMTB score (in seconds) per test moment in TBI subjects, before and after NT training.

LNS Test

The LNS test scores did not show a particular trend, but varies greatly among subjects between test moments 1 and 2 as shown in Figure 4.

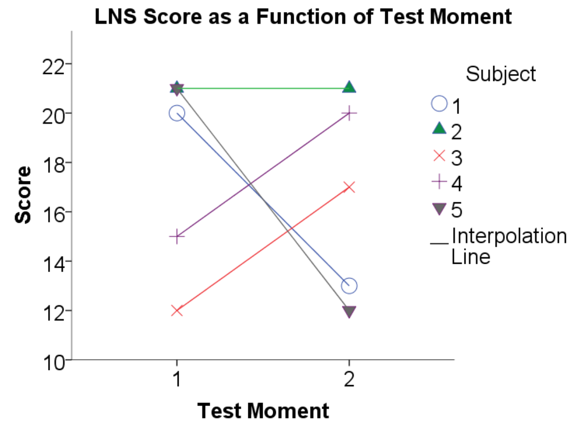

Figure 4: Scatterplot shows LNS results of TBI subjects on test moment 1 and 2

Neurotracker

The scatterplot in Figure 5 shows an overall increase in NT scores over the period of 5 weeks (21sessions). Every individual shows a progressive line of improvement, regardless of their score at the start.

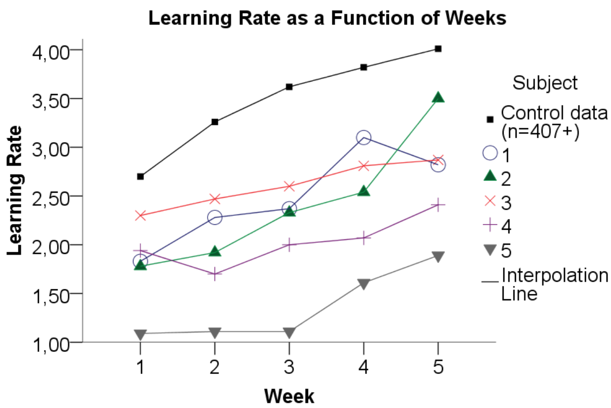

Figure 5: Scatterplot shows NT LR scores per week of TBI subjects & control data

Statistical Significance
Table 1 show mixed results in the paired samples T-tests (95% CI). No statistical significant difference was found in scores between the 2 test moments (T1 and T2) for the TMTA, TMTB and LNS. However, NT 'Learning Rate' scores in the TBI group did show a significant improvement (P= .043) between week 1 and week 5.

Table 1: Statistical Paired Sample T-Test (95%CI Results on Cognitive Test Scores and NT Learning Rate (LR) Scores

Test	Var	T1Mean (SD)	T2Mean (SD)	P value
TMTA	Sec.	26.6(13.6)	25.9(17.7)	.893
TMTB	Sec.	46.6(16.7)	39.8(13.7)	.345
LNS	Score	17.8(4.09)	16.6(4.04)	.461
NT TBI Group	LR	1.79(0.44)	2.73(0.55)	.043
NT Control data	LR	2.7(NA)	4.01(NA)	(NA)

Survey results
Differences in T1 and T2 survey results have been noted in Table 2 as described by the subjects which are classified in ´Objective reports´ (O) noticed by third parties and ´Subjective reports´ (S) noticed by themselves.

Table 2: Reported changes after NT training period, (O) being Objective reports and (S) being Subjective reports.

Subject	Reported Changes Objective (O) and Subjective (S)
1	-No changes
2	-Increased divided attention in traffic situations (S) -Increased peripheral vision in traffic situations (S) -More calm in traffic (S)
3	-No changes
4	-No changes
5	-Decreased motion sickness:(O) Able to perform considerably more spins on axis -Increased divided attention in traffic (S) -Increased focused attention /attention span(O) -Increased (fast) object tracking into distance (S) -More calm in traffic (S)

DISCUSSION
What is the potential of cognitive training software Neurotracker on having a beneficial effect on SPD?

Effect on cognitive functions
No statistical significant difference was found between the two test moments T1 and T2, in the cognitive WAIS test (TMTA TMTB & LNS). The great intra-individual test result differences show no particular coherent trend of improvement in all tests.
Pre-posttest differences measured in cognitive functioning might be too marginal in this pilot and/or not completely sufficient to this type of cognitive testing among TBI subjects and/or may not represent an accurate range of impaired functions of SPD still potentially trainable.

Increased NT scores after training
A significant increase in NT learning rate scores was found (α =.05, P =.043) between the baseline scores (M =1.79, SD = 0.44) and the learning rate scores (M =2.73, SD = 0.55) of week 5.
However because of the rather narrow scope of cognitive measurement used in this research, it is hard to prove or disprove improvement in cognitive functioning as a product of NT training based on these results.
Given the contradicting results of cognitive improvements in prior studies and given the significant improvement NT scores in this study, it is still arguable that NT training does have a positive effect on cognitive functioning in individuals with TBI.

Subjective & objective changes from surveys
Subject #2 subjectively noticed changes which could be translated as increased peripheral vision and divided attention in traffic situations while feeling more calm.
Subject #5 stated to experience an increase in attention span during sports, fast object tracking into distance and a decrease in motion sickness while spinning on axis, up to a year later, this was also objectively confirmed by third parties.

Findings of objective and subjective reports in conjunction with NT scores plead by means of a follow-up study, to further investigate whether NT training could facilitate a positive cognitive transfer in SPD.

CONCLUSION
Since no statistical difference was found between the WAIS TMTA, TMTB & LNS test moments, suggested is no cognitive improvement was found in attention span and working memory.
NT scores did improve with statistical difference possibly contradicting earlier finding of the cognitive tests.
Survey results show subjective an objective reported improvement of visual skills and information processing.

RECOMMENDATIONS
1. It's recommendable for pre-post testing in a follow-up study to use a larger array of cognitive tests to measure more specific cognitive functions associated with SPD during 'SPD tasks' that form an accurate reflection of SPD difficulties in everyday life.

2. Ocular procedural learning may be impaired in individuals with TBI (Kraus et al.2010). Yet still improved by training, Therefore increasing number of sessions might be beneficial since cognitive abilities are still trainable (Parsons B. et al. 2016; Tullo D. et al. 2016).

3. Not all TBI subjects tolerated red-blue 3D-glasses which could be improved using polarized 3D glasses instead which may reduce the amount of conflicting visual information in order to prevent overstimulation of the subjects .

4. Advanced propositions

SPD can be apparent in different (sensory) modalities for example: tactile, auditory and proprioception Increasing training effectiveness by stimulation multiple modalities simultaneously may increase multisensory integration (Lugo et al., 2008; Lugo et al., 2018). By adding a motoric element to NT training a meaningful direction for more advanced future research might be approached.

ROLE OF THE STUDENT

Bernard de Roosz was an undergraduate student working under supervision of Arend de Kloet, associate professor of The Hague University of Applied Sciences (THUAS) and Sophia Revalidatie when the research in this report was performed. The topic, theoretical framework and research design was proposed by Bernard de Roosz and approved by Arend de Kloet to be supervised. Bernard started up the project, Arend introduced the volunteers with TBI, Inge Verhoeven, Neuropsychologist at THUAS Group conducted the psychological tests together with Arend. The training software licenses Neurotracker was provided by Bernard in cooperation with Cognisens while having close contact to the researchers of Cognisens in Canada. The rest of the research was lead, performed and written by Bernard which resulted in a paper.

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